Research Article

Helping the Helpless: Contribution of Rural Extension Services to Smallholder Farmers' Climate Change Adaptive Capacity and Adaptation in Rural Ghana

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Abstract

While there is no doubt that extension services play an active role in promoting smallholder farmers' adaptive capacity and adaptation to climate change, there is a dearth of information and research on how this institution champions climate change adaptation in rural farming communities in Ghana. This study employed a qualitative case study design and interviewed 15 extension officers and 26 smallholder farmers to understand how extension services enhance smallholder farmers' climate change adaptive capacity and adaptation in the rural Adansi North District in Ghana. The findings indicate that extension services adopt multiple strategies to build the adaptive capacity of farmers to climate change. Through the transfer of skills and knowledge, technology and innovations, supply of inputs, technical advice and liaison role with existing local institutions, farmers are able to adapt to climate change. The study further revealed that extension services are hindered by geographical, sociocultural and economic challenges which affect their alignment and fitness to effectively assist smallholder farmers. The study recommends strengthening the capacity of the extension institution. Moreover,

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more experts must be trained to provide special, targeted and important services to smallholder farmers in respect of climate change sensitization and adaptation.

Keywords
Extension services, climate change, smallholder farmers, adaptation, adaptive capacity, Adansi North district, Ghana

Introduction

Climate change is a topical issue for the current generation and without sustainable, effective and innovative strategies, frameworks and programmes, future generations stand at risk to the dire impacts of climate change (Intergovernmental Panel on Climate Change [IPCC] 2018). Chakrabarti (2015) characterizes climate change as all-embracing, all-encompassing and all-pervasive. Climate change affects all regions of the world (FAO 2013: 29–41; FAO et al. 2017; IPCC 2018; World Resources Institute 2011), which explains the all-embracing nature of climate change (Chakrabarti 2015). Thus, climate change is not confined to a particular region as its impacts are differentiated between regions. Nevertheless, substantial evidence in the literature reveals that developing countries particularly in the tropics are more prone and vulnerable to climate change due to the frequent and intense climate variabilities observed in the tropics (AGRA 2014; AUC 2015; Chakrabarti 2015; Chinganya et al. 2014; IPCC 2018).

Climate change is similarly described as all-encompassing which implies that it affects all the living components of the earth's biosphere such as human beings, plant and animals (Chakrabarti 2015; IPCC 2018). Available research indicates that changing climate may pose a serious risk to life on earth and may lead to extinction of plant and animals in the extreme case scenario (IPCC 2018; Xu, Ramanathan and Victor 2018). More importantly, climate change affects air, water, energy and food which is essential for life (Chakrabarti 2015; IPCC 2018) and thus, deemed to be all-pervasive (Chakrabarti 2015). The latest report of the Intergovernmental Panel on Climate Change (IPCC 2018) reveals that future impact of climate will be worse and the brunt will be felt more in developing economies such as Africa and Asia, where livelihoods and economic development are dependent on climate sensitive sectors including agriculture, energy and forestry. The report indicates that a 1.5°C rise in temperature will cripple development, thereby making life on earth difficult by constraining essential resources needed for life and development. More importantly, global sustainable development will be seriously affected at 1.5°C temperature, particularly in developing countries and rural poverty will increase owing to the adverse impact of climate change on agriculture which is a major source of livelihood (IPCC 2018).

Owing to this, global efforts and strategies are needed to tackle climate change. Consequently, global climate change negotiations have attempted to reduce the anthropogenic factors that cause climate change and reduce the impact of climate change through mitigation and adaptation respectively (Chakrabarti 2015; IPCC 2018). According to Collier, Conway and Venables (2008), developed countries

have adopted mitigation as the most appropriate means to tackle climate change while developing countries have focused on adaptation to climate change. Africa's common position on climate change and the African Union's Agenda 2063 stress on the need for climate change adaptation in Africa (AMCEN 2014; AUC 2015). Collier et al. (2008) point out that mitigation is important in developed economies since the impact of climate change is expected to occur in the near future while in the case of developing economies, the impact of climate change is already taking effect. In essence, adaptation strategies are necessary in developing economies to reduce the impact of climate change. Nevertheless, Curtis and Tim (2017) report that climate change adaption costs Africa $10.6 billion annually while mitigation costs the continent about $26 billion every year. This is worrying as Africa, being one of the vulnerable regions, contributes less than 3 per cent to climate change (Nakhooda et al. 2011). Nevertheless, adaptation plays an important role in tackling climate change in Africa, although the effectiveness of climate change adaptation is questionable (Dankelman 2010; Fleurbaey et al. 2014; UNFCC 2011).

Adaptation is basically the strategies and actions undertaken by individuals and groups to reduce the impact of climate shocks and stressors. The German Society for International Cooperation (GIZ 2014) defines adaptation as the adjustment in natural and social systems to respond to the actual or expected climate stimuli with the motive to reduce harm and/or exploit opportunities. Intuitively, climate change adaptations are means (actions, strategies and processes) to an end (reduce impact or explore opportunities). Adaptation can be planned, spontaneous or autonomous (Bryant et al. 2000) and process or concrete based (EEA 2013). Planned adaptation, according to Bryant et al. (2000), occurs in well-organized environment such as government programmes while autonomous adaptation, on the other hand, is peculiar to individuals and households. The European Environment Agency (2013) asserts that process based adaptation enhances capacities of local institutions and local stakeholders to take climate change actions while concrete adaption measures are aimed at improving adaptive capacities. Adaption can also be self-induced or externally planned (Bryant et al. 2000; GIZ 2014; World Resources Institute 2011).

The type of adaptation strategy undertaken is however dependent on the adaptive capacity, purpose, timing, scale and agency of adaptation (Bryant et al. 2000; Fleurbaey et al. 2014; UNFCC 2011). Adaptive capacity is defined as the ability of a system to adapt to or cope with external stressors by modifying its characteristics or behaviour (Adger et al. 2004). In the case of climate change, adaptive capacity allows a system to cope with or take advantage in tackling climate change stressors and shocks (Fleurbaey et al. 2014; IPCC 2007). The adaptive capacity of a system is also dependent on the environment of the system. The social, economic, political and cultural environment of a system have significant impact on its adaptive capacity (IPCC 2007). Adaptive capacity is also closely linked to the purpose of adaptation, which centres on the phenomenon for which adaptation strategies are undertaken and it can be planned or spontaneous (Smit et al. 2000). In rural agriculture communities, adaptation strategies are undertaken to respond to climate shocks and stressors such as flood, drought, rise in temperature and pest invasion among others (Fleurbaey et al. 2014; Melillo et al. 2014).

Regarding the timing of adaptation, Smit and Skinner (2002) posit that adaptation can be proactive, reactive and concurrent. Proactive adaptation goes with planned adaptation while reactive and concurrent adaptation may be planned, spontaneous or autonomous (Smit and Skinner 2002). Individuals and households in rural agricultural communities mostly undertake reactive and concurrent adaptation strategies such as the use of fertilizer, insecticides and weedicides, while institutions particularly public and private may take proactive, reactive and current adaptation strategies (Smit and Skinner 2002). Smit et al. (1999) opine that the time frame within which adaptation is taken may influence the kind of strategy: tactical/short term or strategic/long term. According to Smit and Skinner (2002) and Otitoju (2013), tactical adaptation strategies lead to adjustment over a short period of time such as agriculture season. Smallholder farmers are more likely to undertake tactical adaptation strategies to reduce loss of crops during floods, droughts and pest invasion. Strategic adaptation, on the other hand, leads to structural adjustment in a system over a long period of time (Otitoju 2013; Smit and Skinner 2002). Nevertheless, Otitoju (2013) believes that the timing dimension of adaptation seems more opaque in practice and logical in abstract.

The scale of adaptation may be household, community, regional, national or international (Smit and Skinner 2002) and is influenced by the adaptive capacity of the system which is embodied in physical, social, economic, cultural and political environment of individuals and societies. Studies have demonstrated that smallholder farmers in Africa have low adaptive capacity to climate change, which increases their vulnerability to the actual and expected impact of climate change (AGRA 2014; Chakrabarti 2015; Connolly-Boutin and Smit 2016; Food and Agriculture Organization [FAO], 2012, 2015; Rhiney et al. 2017). That notwithstanding, the agent of adaptation is a critical factor in promoting sustainable climate change adaptation. Even though adaptation may be undertaken by individuals, community, private and public sector (Smit et al. 2000), civil society and non-governmental organizations currently play active roles in climate change adaptation. In agrarian economies like Ghana, extension agents are essential players in promoting climate change adaptation through extension services.

Extension services shape farmers behaviour to respond to, recover from, exploit opportunities and adapt to climate change (Christoplos et al. 2009; Ministry of Food and Agriculture [MOFA] 2007, 2010). More generally, Morrison and Sarris (2007) indicate that extension services actively influence international trade competition, owing to the importance of extension to the global knowledge economy. Through the transfer of knowledge, extension services enable farmers to adopt emerging best practices and innovations to increase agriculture productivity which promotes farmers' development (Boyaci and Yildiz 2016; Christoplos et al. 2009). Globally, extension services significantly contribute to agricultural productivity and development (Boyaci and Yildiz 2016). In Ghana, the importance of extension to rural and national development has been emphasized (MOFA 2016). Ghana's development initiatives towards agricultural development have recognized that promoting rural extension services will serve as a conduit to achieve food security, rural development and address environmental challenges (MOFA 2010, 2016).

However, majority of rural communities in Ghana have high extension service deficits (GSS 2014) due to the large smallholder farmer population who are served by only few extension officers. For instance, in Ghana, the national optimal extension officer:farmer ratio is 1:300 (GSS 2014). However, some rural communities such as the Adansi North District (AND), a rural district located within the Ashanti Region of Ghana, have as high as 1:3500 extension officer:farmer ratio (GSS 2014). This has the potential to render extension services ineffective. In addition, high extension-farmer ratio hinders access to extension service by farmers, thereby crippling the principle of inclusiveness and equity that extension brings to the fore, which are equally fundamental to sustainable development (Fleurbaey et al. 2014). Moreover, in the face of high extension-farmer ratio, the ability of extension services to contribute to agricultural development and enhance smallholder farmers' adaptation and adaptive capacity to climate change can be challenging. It is important for extension services in Ghana to be aligned to meet the growing demands of smallholder farmers and reduce climate change vulnerability (Özerol 2013; Young 2002). The more aligned and fit extension services are to the socioecological and environment needs of farmers, the better and higher the capacity to provide intended services (Özerol 2013; Young 2002).

Ghana's Agricultural Extension Policy (2005) seeks among other things to promote sustainable extension services through decentralized, participatory, pluralism and demand-driven services that meet the increasing needs of farmers particularly at the local level (MOFA 2001, 2005). In addition, the Food and Agriculture Sector Development Policy (FASDEP II) recognizes the need to improve extension services to enhance food security, rural development, poverty reduction, propoor economic growth and agricultural productivity (MOFA 2007). Generally, there is lack of clear linkage between climate change and the objectives of FASDEP II. However, there are strategies in the policy commonly applied to climate change adaptation but not stated explicitly as directed to climate change. Given the threatening effects of climate change, it will be imperative for these key guiding policies to explicitly address climate change issues for a sustainable agricultural system in the country. Given that the climate change impacts pathways in agriculture is bidirectional, strategies and policy interventions should also address how agriculture will contribute less to climate change and vice versa.

The Medium Term Agricultural Sector Investment Plan, which is the current working plan of the Ministry of Food and Agriculture (MOFA) also reveals poor extension services in Ghana (MOFA 2010). This is worrying as climate change threatens food security and livelihood of smallholder farmers (MESTI 2003, 2012, 2013), who are the intended beneficiaries of extension services. Moreover, Vickie (2015) reports that extension policies and associated services in Ghana are constrained by lack of coordination and poor implementation strategies in addition to low capacity of extension service providers. This corroborates the assertion that Ghana lacks strong institutions to address climate change (African Union 2010; AUC 2015; Connolly-Boutin and Smit 2016; Sarpong and Anyidoho 2012; Yaro, Teye and Bawakyillenuo 2014). This therefore brings to the fore the urgent need to strengthen extension services in Ghana, which the present study seeks to contribute to.

To contribute to the extension-climate change debate, this study sought to explore and understand how extension services contribute to smallholder farmers' climate change adaptive capacity and adaptation in the rural AND of Ghana. To achieve this objective, the article addressed the following research questions:

1. What are the participants' perception on the importance of extension services in AND?
2. How do extension services enhance smallholder farmers' climate change adaptive capacity and adaptation in the district?
3. What challenges hinder the effectiveness of extension services to smallholder farmers' climate change adaptive capacity and adaptation in the district?

The study makes significant contributions to strengthen the alignment, fitness and capacity of extension services as agents of adaptation with the potential to promote sustainable climate change adaptation in the district. The proceeding sections present the methods, results, discussion and conclusion of the study.

Methods

Study Design and Participants

An intrinsic qualitative case study which focuses on an individual, a unit or an institution and builds on the lived experiences of the unit/institution or the members making up the group (Stake 1995), was adopted to explore the lived experiences (Creswell 2014; Stake 1995, 2010) of extension services in the rural AND in Ghana. The adopted approach was useful as this study sought to have a better understanding of extension services and climate change adaptation in the district (Njie and Asimiran 2014). Again, the intrinsic case study allowed for an in-depth information from the natural setting of extension providers and smallholder farmers (Creswell 2014; Yin 2004).

The study was conducted in AND. Like other districts in Ghana, a seemingly decentralized structure exists in AND epitomized by the presence of district assembly and local institutions that implement and supervise government interventions and programmes at the local level. The major economic activity in the district is agriculture, particularly subsistence farming which employs about 77 per cent of the active labour force in the district (GSS 2014). The major crops produced in the district include cassava, maize, yam, cocoyam and plantain. Cash crops such as cocoa and oil palm are also produced in the district. As a rural district, poverty, low income, food insecurity and poor access to basic social services and infrastructure are common characteristics in the district (GSS 2014). In addition, there is high extension-farmer ratio of 1:3500 in the district (GSS 2014). Moreover, large household size and high dependency rate in the district compound to increase vulnerability to climate change (GSS 2014).

To understand extension service contributions to smallholder farmer's adaptation to climate change, the study explored the lived experiences in the form of actions, programmes, interventions and strategies implemented in the district by

the MOFA which oversees extension services in the district. Fifteen officers that comprised of Agricultural Extension Agents (AEAs) and District Development Officers (DDOs) of MOFA were purposively selected and interviewed. The inclusion and exclusion criteria included contact with farmers, length of stay in the district and consent to participate in the study. As such, officers with direct contact with farmers, those with more than four years of stay in the district and officers who consented to participate in the study were included in the study. In addition, 26 smallholder farmers were selected and interviewed based on their farming experience, knowledge of climate change and extension services in the district as well as consent to participate in the study.

Data Collection Instruments

The study employed semi-structured interview guide to explore the lived experiences (actions, programmes and strategies) of extension services providers that advance smallholder farmers' climate change adaptive capacities and adaptation in the district. The use of interview was to gain in-depth understanding of the phenomenon under study in the natural setting of the participants (Creswell 2014; Kusi 2012). Moreover, the semi-structured interview guide enabled flexibility in asking question. It also allowed the researcher to probe for further information.

Data Collection Procedure

Face to face and telephone interviews were conducted based on convenience and choice of the participants. Interviews were conducted at convenient location of participants such as workplace, farms and homes. An interview lasted for a duration of 30 minutes to about 1 hour. Data was collected between April and September 2018. Prior to the data collection, the Institutional Review Board of the Institute of Governance, Humanities and Social Sciences of Pan African University in Cameroon approved the study. An initial permission from the district director of MOFA was sought. Upon acceptance and granted permission, the director assisted the researcher in retrieving the list of officers in the district. In all, 20 officers who met the inclusion criteria were identified and approached with consent forms. However, 15 officers agreed to participate in the study, which represents 75 per cent of the identified officers. Although the study reached theoretical saturation with the 12th interview, all consented officers were interviewed.

Out of the 15 officers who participated in the study, there were 4 DDOs and 11 AEAs. In terms of gender, 11 of the officers were males and 4 were females. All the officers have formal education with the lowest education being certificate and the highest being degree. The officers were between the ages of 33 and 59 years. Their years of experience ranged between 5 and 30 years, and they have all lived in the district for over 4 years. In addition, 26 smallholder farmers that consisted 23 males and 3 females, with ages of 40 to 61 years and above participated in the study. Sixteen of the farmers have 30 to 35 years of farming experience while the remaining (10) have over 35 years of farming experience. Eight of the farmers have no formal education as opposed to 18 with formal education.

The researchers provided in-depth information on the objective and significance of the study to the participants. In addition, the participants were informed of their right to exit the interview at any point, voluntary participation, confidentiality as well as the use of their information strictly for academic purpose, and arrangements with participants on mode of interview, date, time and venue for interviews were also made for a smooth process. Also, to ensure anonymity, pseudonyms such as AEA1 and DDO1 for the first AEA and DDO interviewed, respectively, were used. In the case of farmers (smallholder household heads), HH1 represented the first household head interviewed. The interviews were tape recorded with the consent of participants. The use of different sources of information (farmers and officers) helped to triangulate the data for the study. Moreover, the approach also aided in 'thick and rich description', which enabled the study to achieve transferability (Creswell 2014).

Data Analysis

The study analysed data manually through thematic analysis and employed the four stages of thematic analysis of Braun and Clarke (2014), which included coding, theme identification, theme organization and description. To facilitate the analysis, the recorded interviews were listened to consistently and transcribed verbatim to English, as the interviews were conducted in the local language (Twi). The transcription initially involved rough transcription without any editing. The transcripts were later edited for spelling mistakes and grammatical errors. The edited transcripts were rigorously perused to identify themes and sub-themes and draw patterns (Braun and Clarke 2014; Creswell 2014; Kusi 2012; Saldaña 2015). The rigorous perusal enabled the researchers to follow up for clarity in some instances. In addition, the transcripts were shared with participants to confirm and validate the data from the interviews. The researchers coded the transcripts, which aided in the identification and organization of themes and sub-themes (see Table 1). The organization of themes paid particular attention to frequency, differences and similarities of views. A debriefing was held between the researchers on inconsistent themes. The debriefing allowed the researchers to reach consensus on themes that most appropriately served the objective of the study. The agreed themes and sub-themes were then described and interpreted. The findings from the study are presented in verbatim quotes to demonstrate the meanings participants attach to their world as well as their experiences.

Findings

Perception on the Importance of Extension Services in Adansi North District

The participants perceive that extension services are important in the district as the sociocultural, economic, climatic and political nature of the AND warrant the need for external support. The AND is a rural district characterized by low income,

Table 1. Codes, Themes and Sub-themes

Codes	Themes	Sub-Themes
FACTORS	Demand for extension	Rural agrarian district, sociocultural characteristics, economic conditions, climate change, government policies
ADAPTIVE_CAPACITY; ADAPTATION	Training and education	Climate change awareness (cause of climate change, nature of changes, misconception) Farm management (pests and disease, weed control, planting style, adoption and resistance) Agrochemicals application (chemical type, how to apply, when to apply, application requirement, crop nutrients requirements, dress code, lack of knowledge) Pests and diseases (fall armyworms, pests' detection and control, pesticides type, application requirement, spraying time, pheromone traps)
	Inputs supply	Agriculture programmes, types of inputs, terms and conditions
	Spread of innovation	Plantain sucker multiplication, bunds, conservation agriculture, pheromone traps
	Liaison role	Opinion leaders, Farm-based Organizations, livestock vaccination, disaster coordination, health service, education service, agrochemical dealers
CONSTRAINTS	Endogenous	Human resources, technology, finance, facilities/equipment, poor identity, operational areas, gender vulnerability
	Exogenous	Low education, poverty, remote communities, infrastructure, tolerance, cultural beliefs and practices

Source: The authors.

poverty and low level of education particularly among smallholder farmers. Subsistence agriculture, which is the main source of employment and livelihood, is characterized by the application of basic farm tools such hoes and cutlass among others. These factors hinder the ability of farmers to effectively respond to climate change without external support. Extension services are therefore needed by smallholder farmers to enhance their knowledge and skills, increase productivity, reduce poverty and build resilience to climate change. DDO4 highlighted that 'farmers have low level of education and they need us to support their farming and livelihood activities'. In addition, AEA5 reported that 'poverty is too high here and farmers have no proper means to adapt effectively to climate change without our support'.

Extension services play a very critical role as a focal point for implementing government policies and programmes. The policies of government reinforce the need for farmers' adaptation to climate change, and such policies cannot be implemented effectively in rural communities without extension services. Government programmes and interventions particularly the flagship programme, 'Planting for Food and Job', seeks to improve food security and eradicate rural poverty by supporting agricultural activities to increase productivity. Without extension services, farmers in rural communities will be disconnected from the benefits of government policies and programmes. As stated by AEA8, 'we provide support services towards the realization of the government's policies and programmes'. It was also revealed that the decentralized system of administration encourages local support for local development and extension services contribute immensely to the provision of local support to smallholder farmers. This was explicitly revealed by DDO1,

> we are the representatives of the Ministry of Food and Agriculture in the district and we provide a conduit for the implementation of the policies and programmes of the ministry. We work closely with the local communities to know their needs and challenges and provide technical support and advice to promote rural development.

This was concurred by the farmers who intimated that extension officers work with them to implement central government and district administration policies. For instance, a household head stressed that 'without extension officers in the district, farmers will hardly benefit from government agriculture policies such as planting for food and job. They implement government policies for farmers in the district' (HH21). Furthermore, extension services contribute to the realization of the district development agenda through the technical support and advice offered to smallholder farmers. All the officers affirmed that the district seeks to promote rural development through poverty reduction strategies, increase in agricultural productivity, food security, value addition and income generation. Hence, they have a role to play in achieving the district development agenda.

Coupled with the above illustrations, extension services help to enhance smallholder farmers' adaptation and adaptive capacity due to the occurrence of climate change in the district. Participants indicated that the district has observed changes in rainfall season and pattern, rising temperature, destructive winds, floods and droughts. In addition, crop invasion by fall armyworms and grasshoppers have been observed in recent times. These have a significant impact on agricultural activities in the district. Nevertheless, farmers have limited capacities to adapt to these changes

and hence rely on extension services to respond to climate change. Some participants indicated that many farmers have little or no knowledge of climate change, and extension agents therefore help to educate farmer. It emerged that majority of the farmers believe climate change is caused by anger of gods, nature or evil spirits such as witchcraft. AEA1 indicated that '…providing education and training as well as technical support and advice to farmers is very essential to improve their local climate change knowledge and adaptation'. According to HH12, 'with the changes in climate and the invasion of maize crop by new pest species (fall armyworm), we badly need extension services in the district'. It is therefore evident that extension officers are important players in the agricultural system in the district.

Strengthening Climate Change Adaptation and Adaptive Capacity of Smallholder Farmers Through Rural Extension Services

The emerging themes in strengthening climate change adaptation and adaptive capacity of smallholder farmers included training and education, supply of farm inputs, transfer of innovation and technology and liaison role with existing local institutions.

Education and Training on Climate Change

Extension services support smallholder farmers in adapting to climate change through training and education. MOFA, through its extension agents and development officers, educate farmers on climate change as reported by the participants. 'We educate farmers on the cause and effect of climate change' (AEA5). To corroborate this, a participant indicated that 'farmers regularly receive training, education and technical advice from us on climate change' (DDO1). Discussion with the farmers also indicated that extension services serve as an important source of their climate change knowledge as they derive training and education on climate change from extension agents in the district, corroborating the reports from the extension officers. The training and education offered to farmers by extension agents improve local knowledge to climate change and reduce misconception. A participant echoed that '…because most farmers have misconceptions on climate change, we train and educate them to improve their knowledge. We also educate them on what they can do to reduce the impact of climate change' (AEA5). It was revealed in HH7 that

> at first, most farmers thought crop failure, spread of pests and diseases in the district were caused by nature and the anger of god through disobedience and non-compliance to cultural values and practices. However, we currently have better knowledge of climate change through the efforts of the extension officers in the district.

Farmers receive training and education on rise in temperature, erratic rainfall, destructive winds and the spread of diseases and pests in the district. For instance, AEA2 revealed that

> …we have created awareness among farmers on the changes in temperature, rainfall, planting season among others. We educate the farmers that all these observed changes

> are indicators of climate change. We also educate them on fall armyworms. We provide early warning signs to farmers.

Education on Farm Management Practices

Extension officers from MOFA educate farmers on proper farm management practices to reduce the spread of pest and diseases and increase productivity, which was echoed by DDO3 'we educate farmers to constantly clear their farms. The presence of weeds may serve as safe havens for pests and pathogens'. According to AEA7 '…weeds compete with crops for space, soil nutrients and water. So we educate the farmers to regularly clear their farms'. Commenting on the views expressed by the extension officers, HH1 noted that 'although farmers have been clearing their farms from the time of planting to harvesting, we are constantly advised by extension agents to do that regularly'. Nevertheless, regular clearing of farm through labourers or weedicide application according to the farmers increases agriculture expenditure. Aside the control of weeds, farmers also receive training on planting techniques. A participant expressed that 'we also strongly advice farmers to plant in lines particularly for maize to enable easy farm maintenance such as weeding' (AEA11). According to HH6, 'some farmers currently plant their crops particularly maize in lines as propagated by the agriculture officers in the district. Nevertheless, some farmers do not plant in lines as they believe the practice occupies space'.

Education and Training on Proper Application of Fertilizer, Weedicides and Pesticides

The extension officers of MOFA educate and train farmers on the proper application of fertilizers, weedicides and pesticides. AEA1 indicated that 'we educate farmers on when, how and what kind of fertilizer, pesticides and weedicides to apply at various stages of crops'. An officer intimated that 'crops require certain specific nutrients at different stages and we make this information available to farmers through training and education' (DDO4). Some farmers in the district lack knowledge on the proper application of fertilizer, pesticides and weedicides, hence the need for education and training. AEA5 stated that '…most farmers do not have adequate knowledge on the proper application of fertilizer, pesticides and weedicides. They also do not have knowledge on requirements of crops for specific chemicals'. To corroborate this, AEA10 expressed that

> there are fertilizers for cocoa, food and vegetables crops. For cocoa, we have fertilizers like 'Asaase wura' and cocoa feed. There is also NPK 15:15:15 and Urea for vegetables and maize. So, we educate farmers on what kind of fertilizer is appropriate for a particular crop.

Crops have different needs and therefore different fertilizers are applied at different stages of crops. 'In the case of maize, we educate farmers to apply NPK 15:15:15 one to two weeks after planting and from five to six weeks they can apply either Urea or Ammonia' (AEA3). Farmers also receive education on how to dress when applying fertilizers, weedicides and pesticides to prevent health implications. 'We tell farmers to put on protective clothes, mouth and

nose covers, and gloves when spraying their farms' (DDO1). The views of the farmers supported that of the extension officers that indeed, they currently have better knowledge on the available agrochemicals and how they are properly applied through the support of extension officers of MOFA in the district.

Education and Training on Detection and Control of Pests and Diseases (Fall Armyworms)

The district has experienced the invasion of crops by fall armyworms which has been linked to changes in climate. As such, local institutions particularly MOFA provides support to farmers to control fall armyworms invasion. Farmers in the district receive training on early detection of fall armyworms and the proper application of pesticides to control the worms. A participant echoed that

> farmers are trained to scout for the presence of fall armyworms on their farms. Fall armyworms invades maize soon after germination and so we educate farmers to scout their farms for signs of invasion. We tell farmers to inspect the leaves of maize for any foreign signs such as insect bites, eggs and change in colour. (AEA5)

The farmers were equally confident that although fall armyworm is new to them, they are better informed now due to the efforts of extension service providers in the district.

Fall armyworms are difficult to detect at the initial stage of invasion. Therefore, scouting and identification of invasion must be done with due diligence. DDO4 hinted that 'at the initial stage, fall armyworms hide under the leaves of maize and therefore if you only check the surface of leaves you may not notice any invasion. We therefore advice farmers to check under the leaves for signs of fall armyworm invasion'. Early scouting and early detection of fall armyworms enable farmers to control the spread of the pests. AEA4 opined that 'fall armyworms invasion happens very fast and they are difficult to control if not detected very early'. Controlling fall armyworms goes with caution and proper application of pesticides; hence, farmers in the district receive training on proper application of pesticides for fall armyworms control. According to DDO4, 'if you do not apply the chemical properly, you are just wasting your time because the pests will continue to invade your crops. As such, we train farmers on when to apply pesticides, which part of the crop to apply and how to apply chemicals to effectively control fall armyworms'. According to HH13 'had it not been the support from extension officers in the district, majority of us would have been very miserable as we did not have any experience and knowledge of fall armyworms and their control'.

Chemicals to control the worms have specific instructions which are passed on to the farmers through training and education. According to DDO1,

> we have different chemicals like Adepa, KD215, Lunder, Sunpyrifos, K-Optimal and Super Top. To apply KD215, for instance, the farmer has to take 30 ml and mix with water in the knapsack spraying machine. In the case of Adepa Organic Pesticides, it is 100 ml per knapsack. We therefore educate farmers on the specific instructions for each chemical.

To control fall armyworms, spraying is most effectively when the pests are feeding. AEA2 asserted that

> we educate the farmers to spray the pesticides early in the morning because the fall armyworms are active and feed from 5:30 AM to 9 AM. Once the sun shines, you do not spray because the pests burrow deep into the stalk of maize and will not be affected by the chemical. If farmers could not spray in the morning, we advise them to pray between 4:30 PM and 6 PM because the worms feed at this time too.

A farmer hinted that

> …I used to spray fall armyworms with several chemicals and at any time of the day just like I spray cocoa and other crops when affected by pests. It was during famers' meeting that the extension officer educated us on how to appropriately control fall armyworms with pesticides. (HH5)

Aside pesticides, traps are also used in the district to control fall armyworms even though the traps are selective. AEA6 indicated that 'we set pheromone traps in farms to attract and catch male fall armyworms to reduce mating in pests. However, since the trap is made with the pheromone of the female pests, it attracts and catches only the male pests'.

Supply of Farm Inputs

MOFA supplies farm inputs to farmers through the Planting for Food and Jobs programme of the Government of Ghana, which is a programme to reduce poverty through the planting of crops such as maize, rice, cassava among others. The purpose is also to reduce the sufferings of farmers particularly those in rural communities like AND. Some farmers expressed that they have received farm inputs such as improved seeds and fertilizers at subsidized prices from MOFA in the district.

According to AEA8,

> …under the planting for food and job, we supply chemicals to the farmers when they come for seeds and fertilizer. The chemical is to be used to control pests on the farm. Currently, we distribute Adepa Organic Pesticides to farmers whose farms have been invaded by fall armyworms. In 2016, farmers received improved maize seeds for free. We also provided improved rice seeds to rice farmers in 2018. To ensure regular supply of seeds and sustainability of the programme, farmers are required to return the same quantity of seeds received after harvesting.

Transfer of Innovation and Technology to Farmers

The agriculture ministry is also promoting the adoption of improved technologies and innovations to increase productivity of crops in the district. Currently, plantain sucker multiplication, conservation no-tillage agriculture and creation of bunds are some of the innovations adopted in the district. The plantain sucker multiplication technology enables farmers to multiply plantain suckers with just a sucker. AEA5 hinted that 'the plantain sucker multiplication is very important for farmers whose farms are located on hilly lands. They cannot carry many suckers uphill. So, the plantain sucker has come to reduce their sufferings. Now with just

one sucker, the farmer can get many suckers'. Although, the innovation has not been fully embraced by farmers in the district, a section of the participants expressed that they have adopted the innovation while others have the knowledge but are yet to implement it. The Japan International Cooperation Agency (JICA) Rice Project helps farmers to create bunds on farms to increase productivity even on small lands.

> Through the JICA Project, we educate rice farmers that the size of the farm does not automatically leads to high yields but rather the proper maintenance of the farm will affect the yields from the farm. Hence, we educate rice farmers to create bunds to conserve water and increase productivity on the farm. With the bunds, any fertilizer the farmer applies remains on the land. Even if the size of the land is small, the farmer can get good yields through the application of the bund innovation. (AEA8)

In addition to plantain sucker multiplication technology, farmers benefit from land conservation technologies. DDO1 asserted that MOFA has embraced conservation no-till agriculture to ensure proper land conservation and management in the district.

> There is this technology coming up and we are quick to involve our officers in it. We took our officers through a training on the technology. The technology is called 'Conservation no till Agriculture' which is similar to the conservation agriculture. In this technology we do not touch the land, we do not burn, we do not plough. We do not have to disturb the land in anyway. To prepare the land, the farmer will have to just spray the land and leave the leaves on the land. The farmer can just start planting without touching the land. This helps to reduce the effects of climate change on agriculture. Ploughing and other activities expose the land to the effects of climate change and therefore this technology seeks to address some of these challenges. (DDO1)

Liaison Role with Local Institutions

The extension officers also coordinate with local institutions such as Farm-based Organizations (FBOs), opinion leaders, health, education and disaster management organizations as well as agrochemical and seed dealers in the district. Extension officers provide training and education to FBOs and opinion leaders in the district.

> We train FBOs and opinion leaders who in turn train farmers in their respective communities. There are also farmer associations for the purpose of training and securing loans and other financial assistance. We also organize community fora to listen to the challenges of farmers and how best we can cooperate to remedy their challenges. Some of the fora are also organized at our office for farmers and opinion leaders who will be helpful in training farmers in their communities. (DDO4)

For livestock farmers, extension officers undertake community vaccination to reduce and prevent the spread of diseases in livestock.

> …when Ghana was celebrating its 50th Anniversary, the government provided vaccines that were used to control diarrhoea and pneumonia diseases (frequent watery mouth and stool)

> of goats during the raining season which helped to reduce loss of livestock. We also undertake regular visit to communities to know the status of livestock keeping and advise them on best practices. (DDO3)

A farmer hinted that 'although I receive veterinary services from MOFA agents in the district, the services are expensive for an ordinary farmer' (HH7).

There is also coordination with other local institution to reduce climate change vulnerability and impact in the district. For instance, during disaster such as floods and bush fires, MOFA collaborates with the National Disaster Management Organization (NADMO) to support victims through the supply of food, shelter and clothing. This helps in recovery and stabilization of affected communities and households. The emergency task force of NADMO collaborates with MOFA's extension officers to ensure quick response measures during disaster to mitigate and reduce the impact of disasters. NADMO equally collaborates with other existing institutions and stakeholders in the district to strengthen post-disaster reconstruction and rehabilitation. These institutions include the district assembly, Ghana Health Service, Ghana Forestry Commission, Ghana Education Service, Ghana National Fire and Rescue Service, MOFA, Ghana Police Service, traditional and religious leaders as well as Non-governmental and Civil Society Organizations. In addition, there is also the liaison role between the extension officers and agrochemical and seed dealers in the district, in response to their service delivery. DDO4 indicated that 'we work with chemical and seed dealers in the district. With fall armyworm invasion, we collaborate with seed and chemical dealers to advice farmers on the selection and application of chemicals'.

Challenges in Promoting Effective Adaptation Strategies

In an attempt to build the adaptive capacity of smallholder farmers and reduce the impact of climate change on livelihoods and food security in rural communities, extension service providers encounter challenges that potentially hinder their effectiveness. The participants revealed some challenges that affect the capacity of extension services to address the challenges of climate change. These challenges are embedded in the ecological and sociocultural environment of local extension officers and smallholder farmers. Hence, we discuss the challenges as endogenous and exogenous.

Endogenous Challenges

The endogenous challenges identified are those that are under the control of the extension officers and their institutional support systems. Majority of the officers indicated that they are not fully equipped technically, technologically and financially which hinder the effectiveness of extension service delivery in the district. The lack of necessary tools and equipment needed for full operation and alignment to the needs of the communities was also another challenge that was tabled. For instance, almost all the officers expressed that transportation to their operational areas was a major challenge due to inadequate resources. DDO3 stated that '…the transportation to visit all communities is a great challenge and I sometimes

have to use my pocket money to visit communities'. Others indicated that the availability of motorbikes/motorcycles is a prerequisite for extension services in rural communities but there are no motorbikes in their case to aid extension services delivery.

The officers also reported the lack of protective clothing and boots among others which could give them unique identification as extension officers. According to AEA7,

> we are always in the bush with farmers and when farmers are going to their farms they mostly have protective boots and clothing to prevent any danger. Extension officers visit farms and communities with normal dresses. What identifies us as extension officers? We do not have wellington boots, protective clothes and others that can identify us as officers while protecting us from harm. Nurses and other institutions have uniform clothing that easily makes them known.

It is evident that logistical arrangements for these officers to execute their roles have not been made as required and that poses a serious threat for the effectiveness of extension services. The lack of proper identity could also expose officers to dangers, especially when they are seen as intruders during their routine monitoring and inspections.

> I may be going through a cocoa farm and I may spot some cocoa that have been infested. As an officer, I need to examine it or pluck and bring it to the office for examination but I can be chased or even be beaten as a thief in some communities. What shows that I am an extension officer?

Identification of extension officers is therefore necessary for the smooth running of their services.

Some officers revealed that large operational areas assigned to them make it impossible to effectively supervise all communities.

> My operational areas comprises of several large and small communities and I must admit that it is very difficult for me to visit and supervise all communities. Moreover, there are several hundreds of farmers in each community and therefore I cannot effectively supervise them alone. (AEA7)

Nevertheless, farmers concurred that although the population of farmers in the district is large, there are very few agriculture officers stationed in the district to serve the large population of farmers. Some participants reiterated the need to recruit more extension officers to reduce their loads and improve their extension services. For instance, HH19 reiterated that 'the government needs to bring more officers here'. This corroborates the purported large extension:farmer ratio prevailing in the country's agricultural system in general.

Women officers also expressed concerns about their security and vulnerability. AEA6 indicated that

> I am a woman and I visit my operational area alone without anyone to accompany me. Sometimes, I feel very vulnerable especially when I go to inspect farms of male farmers.

> We have had reports of female officers maltreated by male farmers in other districts and sometimes I get scared.

Others indicated that the presence and company of undergraduate interns serving their national service, often referred to as service personnel, helps to reduce their fear, thereby making them secured. 'Sometimes, service personnel accompany us to our operational areas and that makes us feel comfortable but after the end of their one year of service, they are not retained and hence we come back to square one' (AEA5).

Exogenous Challenges

The exogenous challenges, on the other hand, are not directly under the control of the extension officers but pertain in the community and the people they serve. These challenges identified include low education and financial status of farmers, remote communities and sociocultural/religious beliefs of the communities they serve. Majority of the farmers have low or no education which makes extension services difficult because these farmers have built their indigenous knowledge systems and accepting changes becomes difficult. Famers are adamant to follow improved best practices and technical advice, especially when it comes to following instructions on manuals due to their illiteracy levels. DDO1 indicated that

> …if you tell the farmer to do this, you will come back to see that the farmer has done it in a different way. There are times the farmer will not even follow or accept the instructions and information given. They are familiar with traditional way of doing things and hence do not easily embrace change.

Concurring with the officers, a section of farmers noted that they have no education and are used to traditional farming practices. Nevertheless, HH16 cautioned that '…officers should be patient with us and have time for us'.

Lack of education coupled with low financial status of rural farmers hinder the adoption of emerging technologies and innovation. Most farmers earn very low income which is used to cater for their families and manage their farm activities. According to AEA1, 'if you tell the farmer to apply fertilizer, pesticides or weedicides, the first response you will get is I do not have money or the government must supply these inputs'. The farmers expressed that low income and poverty hinder them from embracing modern farming practices although some are aware of the benefits. Nevertheless, even in situations where the farm inputs are supplied, some farmers cannot read the application instructions. The remoteness of some communities under the operational areas of these officers was also reported to hinder effective supervision coupled with the fact that transportation is equally a challenge. 'I cannot go to my operation area and return the same day. The communities are very remote and there are no roads too. The most convenient means to go to my operational area is to use motor which I do not have' (AEA6).

A participant stated that the sociocultural structure of some communities equally pose challenges to effective extension services. 'Some communities associate climate change to anger of gods which influence their adaptation. By associating climate change to anger of gods, there is the belief that nothing can be done except through

traditional means such as pouring libation to pacify the gods' (AEA7). Moreover, the practices of some communities is problematic to effective supervision.

> In my operational area, you cannot reach female farmers without seeking permission or passing through their husbands. I am a woman and therefore I do not face much challenge in approaching male and female farmers but male extension officers will certainly face challenges if they have to operate in my area because of the cultural setting. You know women play active role in agriculture in rural communities and they cannot be left out. (AEA6)

Discussion and Conclusion

Through a qualitative case study, we have provided insights into the understanding of how extension services, amidst the challenges bedevilling their operations, build smallholder farmers' adaptive capacity and promote climate change adaptation in rural communities in AND of Ghana. The participants perceived that extension agents are important stakeholders in the agriculture system in the district. To meet the needs of smallholder farmers, the sociocultural, economic, political and climatic environments of communities and smallholders in the district influence the alignment, fitness, behaviour and norms of extension service providers. The critical role of extension services in building the adaptive capacities of smallholder farmers to promote effective and sustainable adaptation has also been revealed. The service delivery and support systems of extension services influence the behaviour of smallholder farmers to adapt to climate change. This concurs with the assertion that the success and failure of smallholder farmers' climate change adaptation is dependent on existing institutions such as extension (Christoplos et al. 2009). The findings are teased out under the following themes:

Extension as Conduit for Knowledge and Skills Transfer

Extension agents transfer knowledge and skills to farmers through training and education to update farmers on best and emerging practices (Yaro et al. 2014). The transfer of knowledge by extension services has been reported in previous studies (Bhattacharyya et al. 2018; Boubaker et al. 2017; Boyaci and Yildiz 2016; Mamun-ur-Rashid, Gao and Alam 2018). The knowledge and skills acquired through training and education help farmers make informed decisions to improve productivity, food security and livelihood of rural households. Moreover, the transfer of knowledge enhances local climate change knowledge which is essential to reduce misconceptions of climate change by smallholder farmers. Existing literature reveals that smallholder farmers' perception of climate significantly influence coping and adaptation responses (Abid et al. 2015; Fadina and Barjolle 2018). Therefore, the role of extension officers in awareness creation is imperative to adapt to and reduce the impact of climate variability and change. Extension services also facilitate smallholder farmers to embrace technology-oriented and innovative practice to advance their farming activities. This finding concurs with the findings of Bhattacharyya et al. (2018) on how e-extension services help smallholder farmers in India to adopt innovative practices. The findings from the

study indicated that through extension services, smallholder farmers in the district have adopted innovative farming practices such as conservation no-till agriculture, plantain sucker multiplication, bunds for rice farming and the use of pheromone traps to control fall armyworm invasion.

Extension Services as Livelihood and Food Security Support Systems

Smallholder farmers' livelihoods are dependent on subsistence farming which is characterized by low income. Local extension provide essential services that improve the livelihood and food security of rural households. The supply of farm inputs such as fertilizer, weedicides, pesticides and improved seeds enhances farmers' ability to adapt to climate change and increase productivity with a corresponding increase in incomes. Osifo and Obeki (2016) found that smallholder farmers in rural communities in Nigeria have enhanced rural development and food security from extension services. The study revealed that extension service providers collaborate with existing institutions in the AND, particularly NADMO, to build resilience and reconstruction of households. The establishment of essential amenities such as schools, hospitals, roads and market by existing institutions help rural communities to improve their livelihoods. It was revealed that post-disaster reconstruction services enable communities to return to normalcy which is essential for food security and livelihood. These findings are consistent with a previous study (Yaro et al. 2014), which found that local formal and informal institutions help rural communities to respond to and recover from climate shocks and stresses. Similarly, extension service providers assist FBOs to access loans and other financial services which boost productivity, food security and livelihood of farmers.

Extension Services as Adaptive Capacity Builders and Enablers

The availability of resources and assets is essential for farmers' adaptive capacity. The study revealed how extension service providers implement policies and make decisions that affect resource mobilization, distribution and acquisition in rural communities through collaboration with existing institutions which enable farmers to adapt to climate shocks and stresses. In a previous study, Yaro et al. (2014) found that education, sanitation and disaster management services of local institutions help households in Northern Savannah region of Ghana to build their adaptive capacity. Özerol (2013) similarly found that the decision-making apparatus in the Harran Plain in Turkey makes irrigation facilities accessible to local farmers which increases their adaptive capacity to cope with droughts. Building and strengthening adaptive capacities of smallholder farmers and rural households increases their ability to cope with current and uncertain future changes (Fleurbaey et al. 2014; IPCC 2007).

Hindrances to Effective Extension Services

Extension service providers are constrained by environmental, technological, financial and human resource challenges that impede the ability to operate at full potential. These factors affect institutional capacity, institutional alignment

and institutional fitness to build adaptive capacity of smallholders and promotes sustainable adaptation. As asserted by Christoplos et al. (2009), institutions positively and negatively influence the success and failure of climate change adaptation. As such, addressing the challenges of institutions and aligning extension services to the socioecological environment of smallholder farmers is very paramount particularly in rural communities where there is little capacity of households and farmers to adapt to climate change. Previous studies have illustrated that low staffing of extension departments hinders access to extension by smallholder farmers (Bhattacharyya et al. 2018; Boubaker et al. 2017). In Sudan, it was found that low number of extension officers, large extension areas, poor budgetary provision for extension and political unrest allowed only 35–40 per cent of farmer's access to extension services (Moffereh, Bilali and Berjan 2015). Another study in Bangladesh by Mamun-ur-Rashid et al. (2018) also found that poor coordination, less adoption of information communication technology and lack of logistics for extension services affect the quality of extension service. The study has demonstrated that extension services in the district are constrained by low staffing, large operational areas, financial, technical and technological challenges. In addition, the sociocultural practices also hinder access to extension services. Moreover, it is revealed that the remoteness of communities and gender problems pose challenge to the quality of extension service delivery. Without appropriate policies, the ability of extension services to promote rural development, food security and pro-poor economic development cannot be realized in Ghana.

Extension service providers must be strengthened with technology, infrastructure and human resources. Adequate logistical arrangements in terms of protective and identifiable apparel and proper transportation systems should be in place for the smooth running of extension services. This will require a sufficient budgetary allocation for rural extension services to counter their financial challenges and promote effective, efficient and sustainable service delivery. Technology and skills transfer to local institution must be at the core in promoting rural extension capacity. There is the need to intensify extension training in tertiary institutions to reduce high extension:farmers ratio and make extension accessible to smallholder farmers in rural communities in Ghana. This also goes with incentivizing extension service providers. With adequate incentives and logistics, more graduates from tertiary institutions will be motivated to deliver extension services. Experts in plant and animal health must be trained to provide essential phytosanitary and veterinary services respectively to smallholder farmers since it appears that extension service is mostly promoted in the crops sub sector. In-service training must be promoted to update the skills and knowledge of institutional staffs. Rural extension training and mass education must be intensified to improve the knowledge base of rural communities. In addition, rural development and social intervention programmes of the Government of Ghana must be intensified to improve rural services, infrastructure, livelihood and food security. While the study recommends the need for a robust and feasible agricultural extension policy in Ghana, it is important that such policy adopts context specific strategies to enhance its effectiveness. This is due to the fact that the rural communities in Ghana exhibit different socioeconomic characteristics which bring to the fore the need for

fit-for-purpose policy implementation strategies. Further study may examine the effectiveness of extension services in promoting smallholder farmers and rural household food security and livelihood in a larger geographical scope.

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References

Abid, Muhammad, J. Scheffran, U. A. Schneider and M. Ashfaq. 2015. 'Farmers' Perceptions of and Adaptation Strategies to Climate Change and Their Determinants : The Case of Punjab Province, Pakistan'. *Earth System Dynamics* 6: 225–43. doi:10.5194/esd-6-225-2015

Adger, W. Neil, Nick Brooks, M. Kelly, Graham Bentham, Maureen Agnew and S. Eriksen. 2004. 'New Indicators of Vulnerability and Adaptive Capacity'. Norwich, UK.

African Union. 2010. *Policy Framework for Pastoralism in Africa: Securing, Protecting and Improving the Lives, Livelihoods and Rights of Pastoralist Communities*. Addis Ababa: Author.

AGRA. 2014. *Africa Agriculture Status Report 2014: Climate Change and Smallholder Agriculture in Sub-Saharan Africa*. Nairobi. Available at https://www.climateinvestmentfunds.org/sites/cif_enc/files/aasr-2014climate-change-and-smallholder-agriculture-in-ssa.pdf (accessed on 17 September 2019).

AMCEN. 2014. *African Strategy on Climate Change*. Available at https://www.un.org/en/africa/osaa/pdf/au/cap_draft_auclimatestrategy_2015.pdf (accessed on 17 September 2019).

AUC. 2015. *Agenda 2063 Framework Document: The Africa We Want*. Available at https://www.un.org/en/africa/osaa/pdf/au/agenda2063-framework.pdf (accessed on 17 September 2019).

Bhattacharyya, Tapas, Vinayak Krishna Patil, S. G. Bhave and Parag M. Haldankar. 2018. 'E-Extension Services of SAUs in Indian Agriculture: Challenges and Management Strategies'. *Advanced Agricultural Research & Technology Journal* 2 (2): 119–25.

Boubaker, Dhehibi, Shinan N. Kassam, Aden Aw-Hassan and Jamal Al Rusheidat. 2017. 'Enhancing Agricultural Extension Services for Rural Development in Jordan'. *International Journal of Agricultural Extension* 5 (2): 51–60. Available at https://esci-journals.net/index.php/IJAE/article/view/2191 (accessed on 17 September 2019).

Boyaci, M. and O. Yildiz. 2016. 'An Overview of Agricultural Extension Services in Turkey'. *Bulgarian Journal of Agricultural Science* 22 (1): 151–57.

Braun, V. and V. Clarke. 2014. 'What can Thematic Analysis Offer Health and Wellbeing Researchers?' *International Journal of Qualitative Studies on Health and Well-Being* 9. doi:10.3402/qhw.v9.26152.

Bryant, C. R., B. Smit, M. Brklacich, T. Johnston, J. Smithers, Q. Chiotti and B. Singh. 2000. 'Adaptation in Canadian Agriculture to Climatic Variability and Change'. *Climatic Change* 45: 181–201.

Chakrabarti, P. G. D. 2015. *Global Sustainable Development Report 2015, Climate Change and Sustainable Development: Assessing Progress of Regions and Countries*. New Delhi: Oxford University Press.

Chinganya, J. M., Vincent Ngeendakumuna, and Caesar Cheelo. 2014. 'Africa Food Security Brief: Special Focus on Climate Change Impacts'. *Department, Africa Food Security Statistics*. Abidjan, Cote D'Ivoire.

Christoplos, Ian, Richard J. T. Klein, Simon Anderson, Katell Le Goulven, Margaret Arnold, Victor Galaz and Merylyn Hedger. 2009. *The Human Dimension of Climate Adaptation: The Importance of Local and Institutional Issues*. Copenhagen: Commission on Climate Change and Development.

Collier, P., G. Conway and T. Venables. 2008. 'Climate Change and Africa'. *Oxford Review of Economic Policy* 24 (2): 337–53.

Connolly-Boutin, Liette and Barry Smit. 2016. 'Climate Change, Food Security, and Livelihoods in Sub-Saharan Africa'. *Regional Environmental Change* 16: 385–99. doi:10.1007/s10113-015-0761-x.

Creswell, Jonh W. 2014. *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. 4th ed. London: SAGE Publications.

Curtis, Mark, and Jones Tim. 2017. 'Honest Accounts 2017: How the World Profits from Africa's Wealth'. http://jubileedebt.org.uk/reports-briefings/report/honest-accounts-2017-world-profits-africas-wealth.

Dankelman, I. 2010. *Gender and Climate Change: An Introduction*. London: Routledge.

EEA. 2013. *Adaptation in Europe: Addressing Risks and Opportunities from Climate Change in the Context of Socioeconomic Developments*. Copenhagen. Available at http://www.eea.europa.eu/publications/adaptation-in-europe (accessed on 17 September 2019).

European Environment Agency. 2013. 'Adaptation in Europe: Addressing Risks and Opportunities from Climate Change in the Context of Socioeconomic Developments'. Copenhagen, Denmark. http://www.eea.europa.eu/publications/adaptation-in-europe.

Fadina, Roland and Dominique Barjolle. 2018. 'Farmers' Adaptation Strategies to Climate Change and Their Implications in the Zou Department of South Benin'. *Environments* 5 (1): 15. doi:10.3390/environments5010015.

FAO, IFAD, UNICEF, WFP, and WHO. 2017. 'The State of Food Security and Nutrition in the World 2017. Building Resilience for Peace and Food Security'. Rome. http://www.who.int/nutrition/publications/foodsecurity/state-food-security-nutrition-2017-inbrief-en.pdf?ua=1.

Fleurbaey, Marc, S. Kartha, S. Bolwig, Y. L. Chee, Y. Chen, E. Corbera, F. Lecocq, et al. 2014. 'Sustainable Development and Equity'. In *Climate Change 2014: Mitigation of Climate Change: Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, et al., 283–350. Cambridge and New York, NY: Cambridge University Press. Available at https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_full.pdf (accessed on 17 September 2019).

Food and Agriculture Organization (FAO). 2012. *Smallholder and Family Farmers: Fact Sheet*. Rome. Available at http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_SMALLHOLDERS.pdf (accessed on 17 September 2019).

Food and Agriculture Organization (FAO). 2013. 'Food Security Dimensions at the National Level'. *State of Food Insecurity in the World*. Available at http://www.fao.org/3/a-i3434e.pdf (accessed on 17 September 2019).

———. 2015. *Country Fact Sheet on Food and Agriculture Policy Trends: Ghana*. Accra. Available at http://www.fao.org/3/a-i4490e.pdf (accessed on 17 September 2019).

GIZ. 2014. *The Vulnerability Sourcebook: Concepts and Guidelines for Standardized Vulnerability Assessment*. Eschborn, Germany: GIZ.

GSS. 2014. *2010 Population and Housing Census: District Analytical Report, Adansi North District*. Accra: Author.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, MA: Cambridge University Press.

———. 2018. *IPCC Special Report on the Impacts of Global Warming of 1.5°C—Summary for Policymakers*. Incheon. Available at http://www.ipcc.ch/report/sr15/ (accessed on 17 September 2019).

Kusi, H. 2012. *Doing Qualitative Research: A Guide for Researchers*. Accra New Town: Emmpong Press.

Mamun-ur-Rashid, Md, Qijie Gao and Oliul Alam. 2018. 'Service Quality of Public and Private Agricultural Extension Service Providers in Bangladesh'. *Journal of Agricultural Extension* 22 (2). doi:10.4314/jae.v22i2.13.

Melillo, J. M., R. Terese, and W.Y. Gary. 2014. 'Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment'. New York, NY.

MESTI. 2003. *Climate Change Technology Needs and Needs Assessment Report*. Accra: Author.

———. 2012. *Ghana National Climate Change Adaptation Strategy*. Accra: Author.

———. 2013. *Ghana National Climate Change Policy*. Accra: Author.

Ministry of Food and Agriculture (MOFA). 2001. *Agricultural Extension Policy (Final Draft) April 2001*. Accra: Author.

———. 2005. *Agricultural Extension Policy* (Abridged Version). Accra: Author.

———. 2007. *Food and Agriculture Sector Development Policy (FASDEP II)*. Accra: Author.

———. 2010. *Medium Term Agriculture Sector Investment Plan (METASIP) 2011–2015*. Accra: Author.

———. 2016. *Agriculture in Ghana Facts and Figures (2015)*. Accra. Available at https://www.agrofood-westafrica.com/fileadmin/user_upload/messen/agrofood-Westafrica/Brochure/AGRICULTURE-IN-GHANA-Facts-and-Figures-2015.pdf (accessed on 17 September 2019).

Moffereh, Igbal Osman, Hamid Bilali and Sinisa Berjan. 2015. 'Extension Services in Sudan: An Overview'. In *Sixth International Scientific Agricultural Symposium, Agrosum 2015*, edited by Dusan Kovacevic, 769. Jahorina: University of East Sarajevo, Faculty of Agriculture, Republic of Srpska, Bosnia.

Morrison, Jamie and Alexander Sarris. 2007. *WTO Rules for Agriculture*. Rome: FAO.

Nakhooda, Smita, Alice. Caravani, Allister. Wenzel, and Liane Schalatek. 2011. 'The Evolving Global Climate Finance Architecture'. London.

Njie, Baboucarr and Soaib Asimiran. 2014. 'Case Study as a Choice in Qualitative Methodology'. *IOSR Journal of Research and Method in Education (IOSRJRME)* 4 (3): 35–40. doi:10.9790/7388–04313540.

Osifo, Samuel Jesuorobo and Stephen Obeki. 2016. 'Agricultural Extension Service and Community Development'. *Management Sciences Review* 7 (1): 22–39.

Otitoju, M. A. 2013. 'The Effects of Climate Change Adaptation Strategies on Food Crop Production Efficiency in Southwestern Nigeria'. University of Nigeria, Nsukka.

Özerol, Gül. 2013. 'Institutions of Farmer Participation and Environmental Sustainability : A Multi-Level Analysis from Irrigation Management in Harran Plain, Turkey.' *International Journal of the Commons* 7 (1): 73–91.

Rhiney, Kevon, Anton Eitzinger, Aidan D. Farrell and Michael A. Taylor. 2017. 'Assessing the Vulnerability of Caribbean Farmers to Climate Change Impacts: A Comparative Study of Cocoa Farmers in Jamaica and Trinidad'. In *Climate Change and Food Security: Africa and the Caribbean*, edited by Elizabeth Thomas-Hope, 59–69. Abingdon, United Kingdom: Routledge. Retrieved from http://doi.org/10.4324/9781315469737

Saldaña, J. 2015. *The Coding Manual for Qualitative Researchers*. Thousand Oaks, CA: SAGE Publications.

Sarpong, Daniel Bruce and Nana Akua Anyidoho. 2012. *Climate Change and Agricultural Policy Processes in Ghana*, Working Paper No. 045. Accra. Available at http://www.hubrural.org/IMG/pdf/fac_working_paper_045_cc_and_agricultural_policy_processes_in_ghana.pdf (accessed on 17 September 2019).

Smit, Barry, Ian Burton, R.J.T. Klein, and R. Street. 1999. 'The Science of Adaptation: A Framework for Assessment'. *Mitigation and Adaptation Strategies for Global Change* 4 (3–4): 199–213.

Smit, Barry, I. Burton, R.J.T. Klein, and J. Wandel. 2000. 'An Anatomy of Adaptation to Climate Change and Variability'. *Climate Change* 45: 223–51. doi:10.1023/A:1005661622966.

Smit, Barry, and M. Skinner. 2002. 'Adaptation Options in Agriculture to Climate Change: A Typology'. *Mitigation and Adaptation Strategies for Global Change* 7: 85–114. doi:10.1023/A:1015862228270.

Stake, Robert E. 1995. *The Art of Case Study Research*. Thousand Oaks, CA: SAGE Publications.

———. 2010. *Qualitative Research: Studying How Things Work*. New York, NY: Guilford Press.

UNFCC. 2011. 'Fact Sheet: Climate Change Science—the Status of Climate Change Science Today'. *United Nations Framework Convention on Climate Change*. doi:10.1111/j.1467–9388.1992.tb00046.x.

Vickie, Sigman. 2015. *Agricultural Extension Policy Forum: Ghana*. Accra: Modernizing Extension and Advisory Services.

World Resources Institute. 2011. *Making Adaptation Count: Concepts and Options for Monitoring and Evaluation of Climate Change Adapation*. Eschborn. Available at http://pdf.wri.org/making_adaptation_count.pdf (accessed on 17 September 2019).

Xu, Yangyang, Veerabhadran Ramanathan and David G Victor. 2018. 'Global Warming Will Happen Faster than We Think: Three Trends Will Combine to Hasten It'. *Nature* 568: 31–32.

Yaro, Joseph Awetori, Joseph Teye and Simon Bawakyillenuo. 2014. 'Local Institutions and Adaptive Capacity to Climate Change/Variability in the Northern Savannah of Ghana'. *Climate and Development*, September: 37–41. doi:10.1080/17565529.2014.951018.

Yin, Robert K. 2004. *Case Study Research: Design and Methods*. London: SAGE Publications.

Young, O. R. 2002. *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale*. Cambridge, MA: MIT Press.